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RIFUGIO
- RIGOROUS FUSION OF GRAVITY FIELD INTO STATIONARY OCEAN MODELS

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ABSTRACT

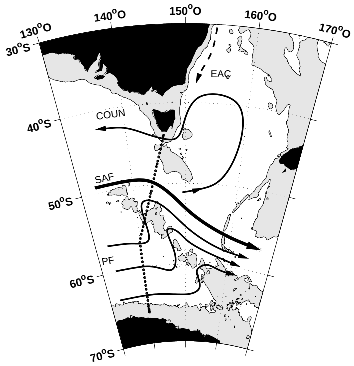
So-called complete gravity field models together with their full error variance/covariance information have recently been designed to be integrated into geo-scientific process models. In our case, the ocean's mean dynamic topography (altimetric mean sea surface referenced to the geoid) is used to improve estimates of the general ocean circulation in the context of stationary ocean models. We want to combine complete gracity field models with altimetric data for which a full error propagation is also implemented in the processing [1]. Thus we derive estimates of the ocean's mean dynamic topography with a regular covariance matrix. The goal of this project is to assess the effects of this data combination on improving ocean models. Preliminary results already show that geoid models developed from GRACE data are, while accurate on very long scales, hardly yet accurate enough for that purpose. We anticipate that the increased accuracy, especially on shorter scales, of gravity measurements from GOCE will contribute to a more realistic description of ocean currents as well as mass and heat transports.

Key words: ocean circulation models; inverse methods; data assimilation; Earth gravity field modeling.

1. INTRODUCTION

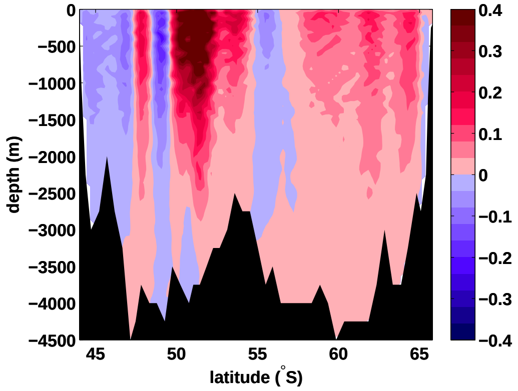
Stationary inverse ocean models compute oceanic flow fields from input variables such as temperature, salinity and current velocities v. These measurements are assimilated into the ocean model, which describes the movement of water masses by physical differential equations. In general theory and data do not agree perfectly, therefore a least squares fit must be performed. A formal error can finally be calculated by inverting the Hessian of the cost function. Unfortunately, it is very expensive and time-consuming to measure in-situ mean velocities of ocean currents.

2. STATIONARY INVERSE OCEAN MODELS



Section model FEMSECT Tasmania - Antarctica.

FEMSECT [2] is a simple two-dimensional ocean model that we applied to the WOCE SR3 section between Tasmania and Antarctica. The available in-situ data for this part of the ocean suffice to calculate an across-section flow field. The integrated mass transport across the section is 159 ± 64 Sv. This large formal error is a result of the measurement inaccuracy.



Velocity field from ocean model without MDT

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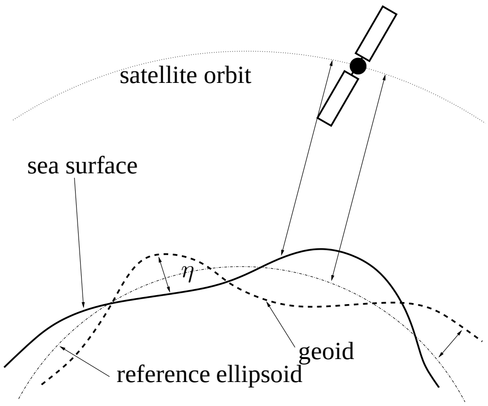
3. GRAVITY FIELD MODELS: OCEAN SURFACE CURRENTS FROM MEAN DYNAMIC TOPOGRAPHY

Surface velocities v can also be determined by the geostrophic relation balance

$$v = \frac{g}{f}\frac{\partial \eta}{\partial x} \tag{1}$$

from the mean dynamic topography η - the departure of the sea surface from the geoid.



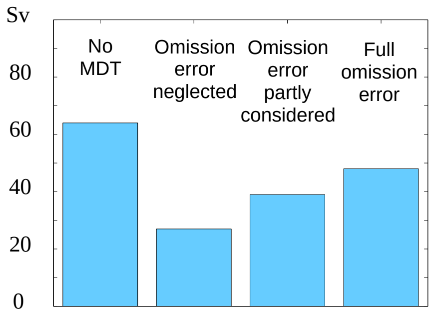
Mean dynamic topography (MDT)

Global gravity field solutions are usually represented by spherical harmonic functions. To be used in an ocean model, the series has to be truncated and projected onto the finite ocean model grid.

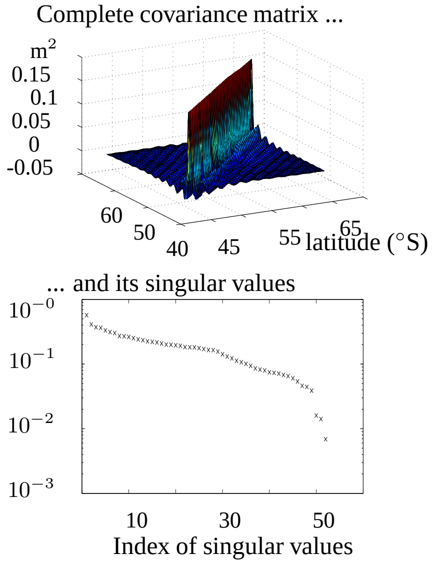
Due to neglecting small scales, the so called omission error occurs and leaks into large scales.

We show: The omission error should be taken into account!!

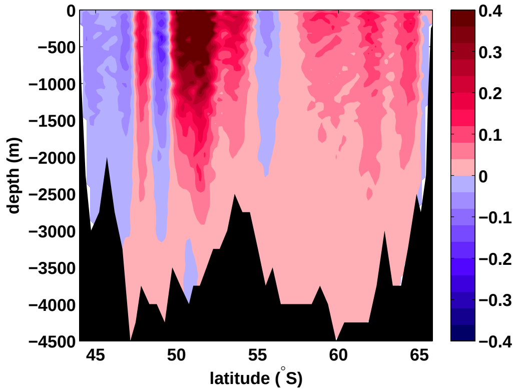
The omission error has considerable influence on the error covariance matrix whose inverse is used as the weighting matrix during the optimization.



Formal errors for transport across section



Error covariance matrix of complete geoid model



Velocity field from ocean model with MDT

3.1. Results

- Mass transport across section: 174 ± 48 Sv (with full omission error)
- The omission error is not negligible for the overall error estimate.
- Considering the omission error reveals that GRACE data are not accurate enough for improving transport estimations by ocean models significantly

$\Longrightarrow$ We expect significant improvements from GOCE with low omission error!

4. OCEAN SURFACE CURRENTS FROM ICE DRIFT: AN ALTERNATIVE APPROACH

The presence of sea ice at high latitudes impedes altimetric measurements. But satellite imagery allows for detection of mean sea ice motion, whose features are mainly attributable to atmospheric forcing.
Surface ocean currents beneath the ice cover can be derived by subtracting the wind effect from the ice motion via

$$\begin{bmatrix}\bar{c_u}\\ \bar{c_v}\end{bmatrix} = \begin{bmatrix}\bar{U}\\ \bar{V}\end{bmatrix} - F\cdot\begin{bmatrix}\cos\theta & -\sin\theta\\ \sin\theta & \cos\theta\end{bmatrix}\begin{bmatrix}\bar{u}\\ \bar{v}\end{bmatrix} \qquad (2)$$

with turning angle

$$\theta = \arctan\left[\frac{\sum u'V' - \sum v'U'}{\sum u'U' + \sum v'V'}\right] \qquad (3)$$

and speed reduction factor

$$\begin{aligned} F &= \frac{\cos\theta\sum u'U' + \sin\theta\sum v'U'}{\sum u'^2 + \sum v'^2} \\ &+ \frac{-\sin\theta\sum u'V' + \cos\theta\sum v'V'}{\sum u'^2 + \sum v'^2}, \end{aligned} \qquad (4)$$

with $u' = u - \bar{u}, \quad v' = v - \bar{v}$, etc. [3]

With this approach, the resulting mass transport across the section is 173 ± 46 Sv.

$\Longrightarrow$ The error reduction is of the same scale as in the MDT assimilation case.

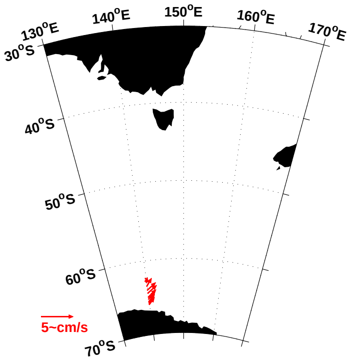
4.1. Outlook

To improve this estimate, we would need:

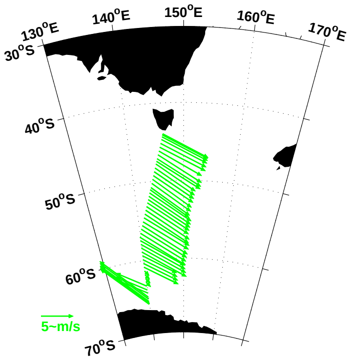
- refined radar imagery
- more reliable wind field
- improved image processing techniques
- error variance/covariance information!

This is far from being realized.

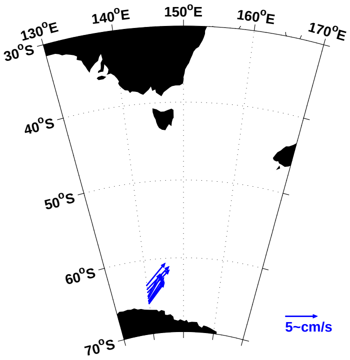
$\Longrightarrow$ Therefore, we hope for GOCE to improve accuracy of the mean dynamic topography!



Mean ice drift data (Polar Pathfinder, NSIDC)



Mean wind data (NCEP reanalysis)



Resulting mean ocean surface current

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